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By

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ABSTRACT

The distribution and monthly occurrence of Gymnodinium breve, the Florida red-tide organism, were determined over a period of 13 months (in 1964-65) in the coastal waters of west Florida. Counts of G. breve varied from 0 to 53,800 cells per liter of water; no fish kills were observed. The organism was present at all stations from 9.3 km. (5 miles) to 37.1 km. (20 miles) offshore. It was not present in samples from Tampa Bay, and it was found only twice in samples from Charlotte Harbor. The highest occurrence of G. breve was in samples taken 27.8 km. (15 miles) offshore. Vertical distribution of the species was greatest at the surface and at 5 m. and lowest at 20 m. The largest concentrations of G. breve occurred in September during a period of reduced salinity and temperature. Because these two factors are important to the ecology of the organism, their relation to the presence or absence of G. breve is discussed. G. breve were found within the temperature range 13.8° to 30.6° C. It was absent or rare at both the low and high temperatures; cell densities greater than 1,000 per liter were observed from 26.0° to 27.9° C. The organism occurred at salinities ranging from 33.68 to 37.07 p.p.t. The highest concentration of cells and incidence was noted within the salinity range 35.00 to 36.90 p.p.t.

INTRODUCTION

Gymnodinium breve Davis is the nonthecate dinoflagellate that causes red tide in estuarine and neritic waters along the west coast of Florida. Dense concentrations of the organism discolor the water and produce toxic metabolites that cause catastrophic mortality among fishes and other marine animals. References to previous reports on the distribution and seasonal occurrence of G. breve were presented by Finucane (1964). Rounsefell and Nelson (1966) reviewed published and unpublished papers and data on red tide, and Rounsefell and Dragovich (1966) examined the relation between oceanographic factors and abundance of the Florida red-tide organism. At the Red-Tide Symposium held in October 1964 at St. Petersburg Beach, Fla., past and current red-tide research was examined and several suggestions for future studies were presented (Sykes, 1965).

This study presents information on the seasonal occurrence and distribution of G. breve in an area of recurrent red-tide outbreaks covering about 2,800 sq. km. (1,600 square miles) along the west coast of Florida. Systematic monthly collections of such magnitude to monitor G. breve and observe oceanographic conditions have not been made previously in the region. Our work made it possible to corroborate and extend information on several aspects of the ecology of G. breve in Florida waters.

SAMPLING METHODS AND LABORATORY TECHNIQUES

From February 1964 through February 1965, water samples were collected monthly to determine the abundance of G. breve and to measure water temperature and salinity. We established 22 stations in Tampa Bay, Charlotte Harbor, and at regular intervals along a series of transects extending 37.1 km. (20 miles) offshore (fig. 1). The water column was sampled during daylight at 5-m. intervals

[1] Contribution No. 30, Bureau of Commercial Fisheries Biological Laboratory, St. Petersburg Beach, Fla.

from surface to bottom. Collecting procedures, techniques of enumerating G. breve, and temperature and salinity determinations were identical to those described by Dragovich, Finucane, and May (1961). The data on precipitation were obtained from the U.S. Environmental Science Service Administration.

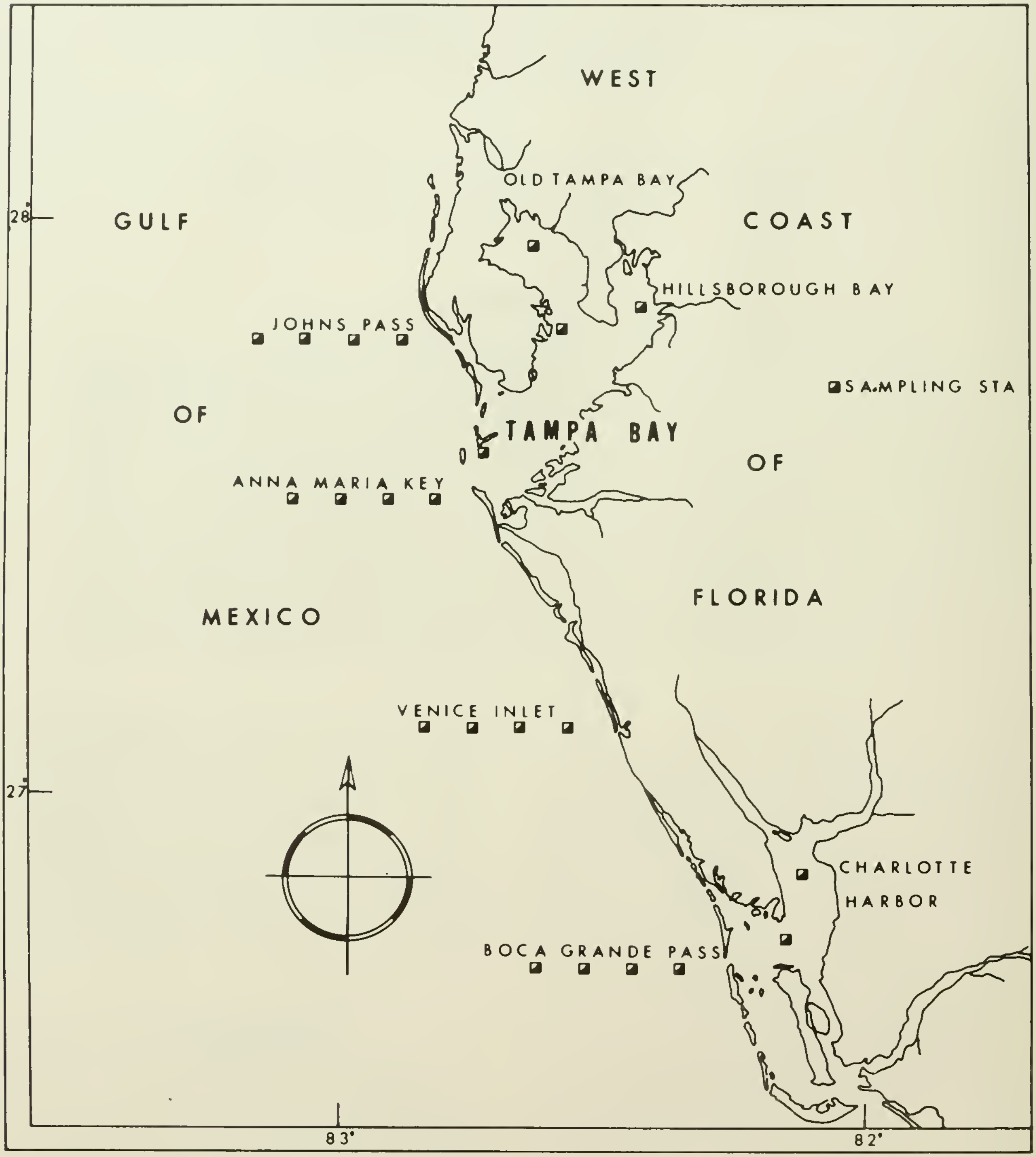

Figure 1.--Sampling stations along the west coast of Florida.

The term "bloom" used in this paper follows the definition by Finucane (1964): "Any concentration of G. breve exceeding the normal population level of approximately 1,000 cells per liter." During previous red-tide studies, lethal blooms of G. breve usually consisted of 250,000 organisms per liter or more (Finucane and Dragovich, 1959).

DISTRIBUTION OF GYMNODINIUM BREVE

The distribution of phytoplankton may be portrayed as 4-dimensional, consisting of latitudinal, longitudinal, vertical, and temporal components. In this paper, distribution is examined primarily in the light of previous studies of the Florida red tide (Dragovich, 1961; Finucane, 1964).

Geographic Distribution

G. breve was found in 24 percent of all samples, and was present in one or more collections at all offshore stations in concentrations of <10 to 53,800 cells per liter (figs. 2a, 2b, 2c, and 2d). The scale shown in the legend of the figure represents only one-half of the profiles; September values are shown with interrupted lines because they exceed scale. The top value (September) represents the number of cells at the surface; the lower, cells at 5 m.

The percentage of samples in which G. breve occurred (hereafter identified as incidence) was highest (32.3 percent) at stations off Venice Inlet, lowest at stations off Boca Grande Pass (23.0 percent), and intermediate off Anna Maria Key (29.7 percent) and Johns Pass (29.0 percent). In terms of distance from shore, incidence of G. breve was highest at the 27.8-km. (15-mile) stations and least at the 9.3-km. (5-mile) stations (fig. 3).

G. breve was absent from all Tampa Bay samples and was recorded at Charlotte Harbor only in April and July, in concentrations of less than 100 cells per liter.

Monthly Occurrence

Counts of G. breve were less than 1,000 per liter in each month except February and September. After the high incidence in February 1964, numbers declined in March and April and remained relatively low through August. Both numbers and incidence increased at all offshore stations in September, and cell counts were higher than in any previous month. Numbers decreased in October and November, when monthly incidence was the lowest during the study. Both numbers and incidence increased again in December. The incidence in that month was highest 27.8 km. (15 miles) and 37.1 km. (20 miles) offshore from Johns Pass, Anna Maria Key, and Venice Inlet; samples off Boca Grande yielded no G. breve. Adverse weather in January and February 1965 prevented collections at some stations, but in the areas sampled (Tampa Bay, Johns Pass, and Venice Inlet), the incidence of G. breve was low.

Vertical Distribution

G. breve was collected at least once during the study at each offshore station and each sampling level. The highest incidence of the organism was at the surface (33.3 percent) and at 5 m. (30.5 percent), lowest at 20 m. (20.7 percent), and intermediate at the 10- and 15-m. levels. Samples containing 1,000 cells or more per liter were recorded only at the surface and at 5 m. (figs. 2a and 2c); 67 percent of these high counts were at the surface. Finucane (1964) also observed higher incidence of G. breve at the surface than at the bottom.

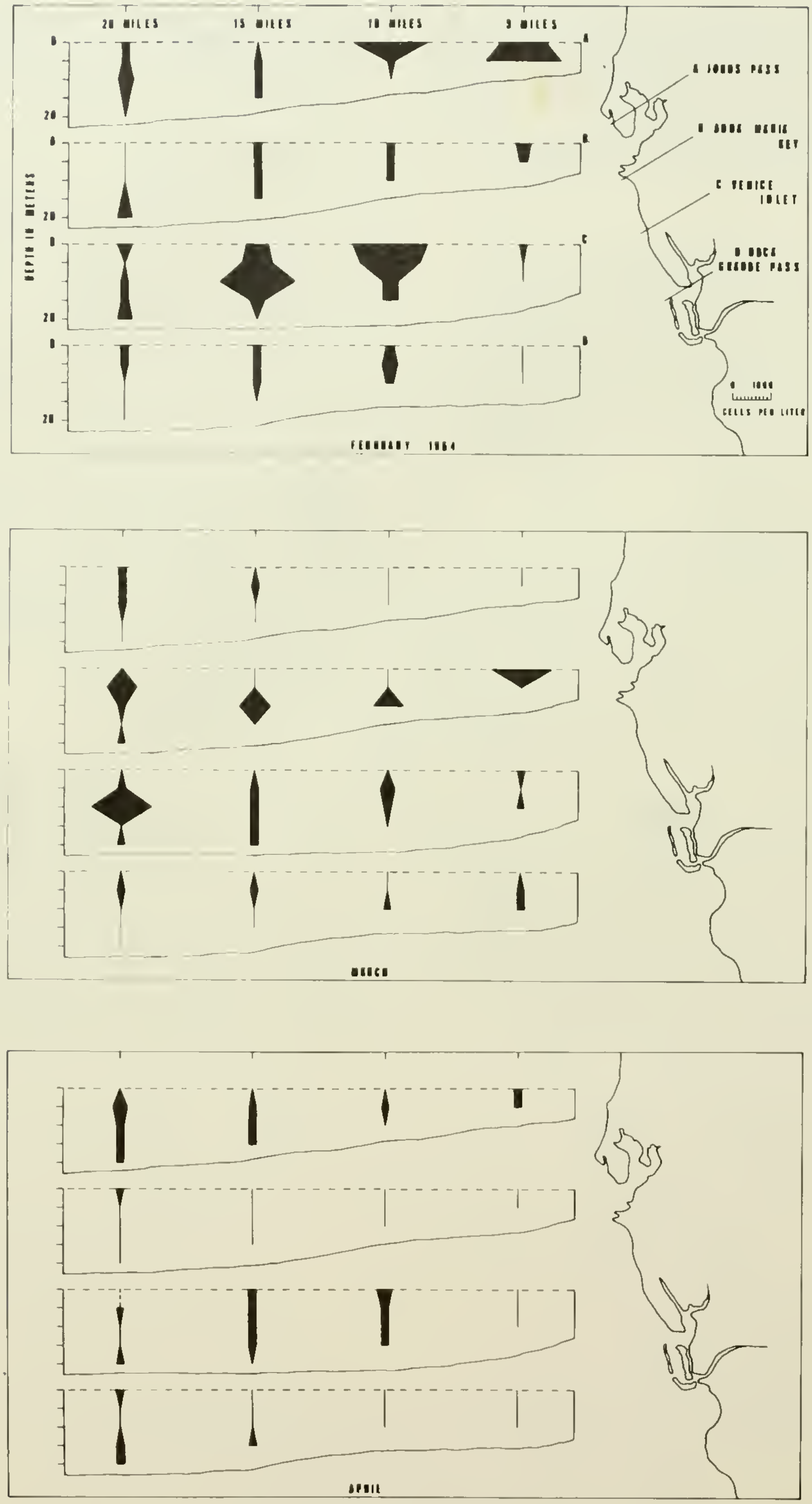

Figure 2(a).--Vertical and temporal distribution of G. breve at sampling areas along the west coast of Florida.

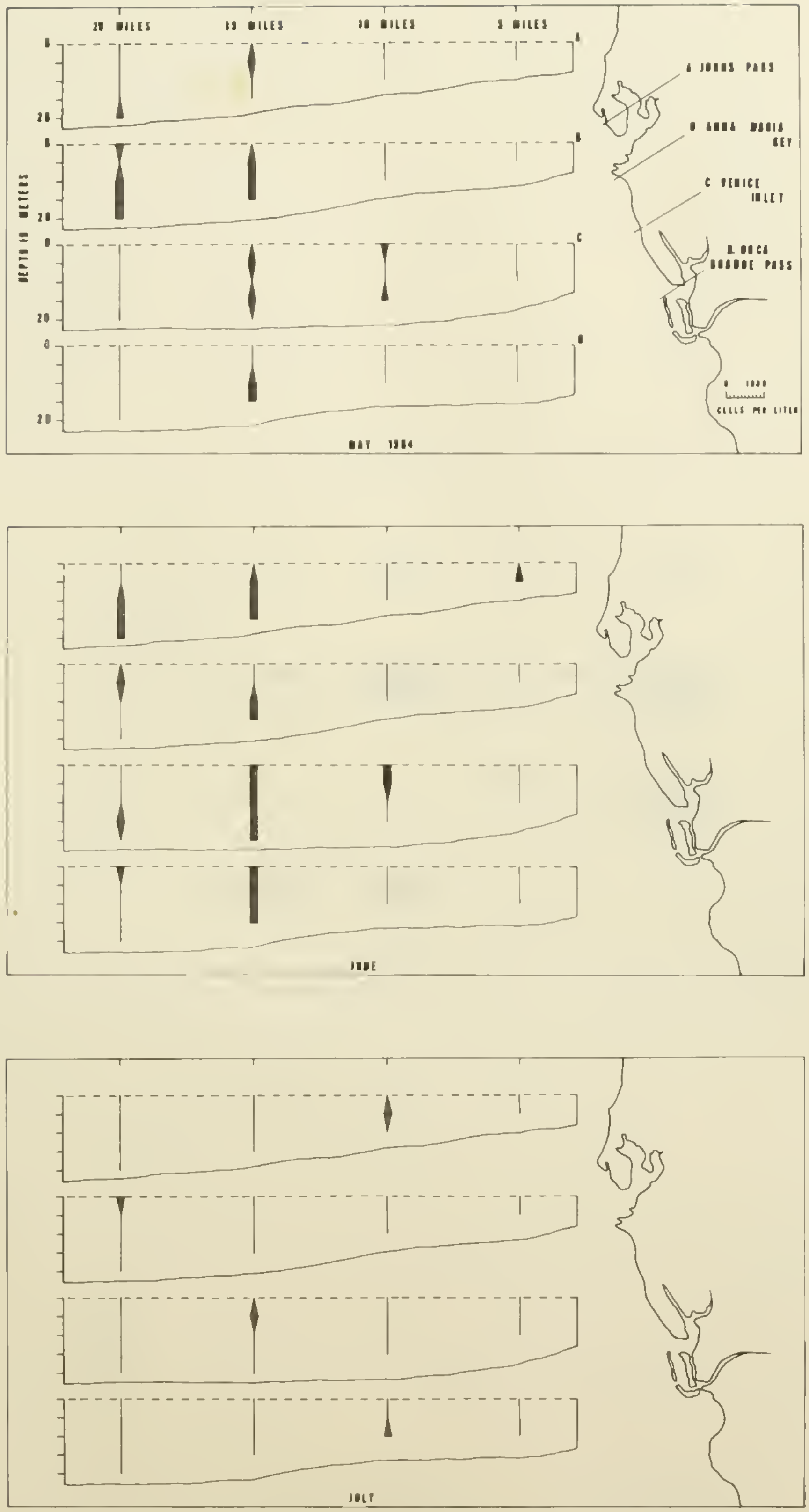

Figure 2(b).--Vertical and temporal distribution of G. breve at sampling areas along the west coast of Florida.

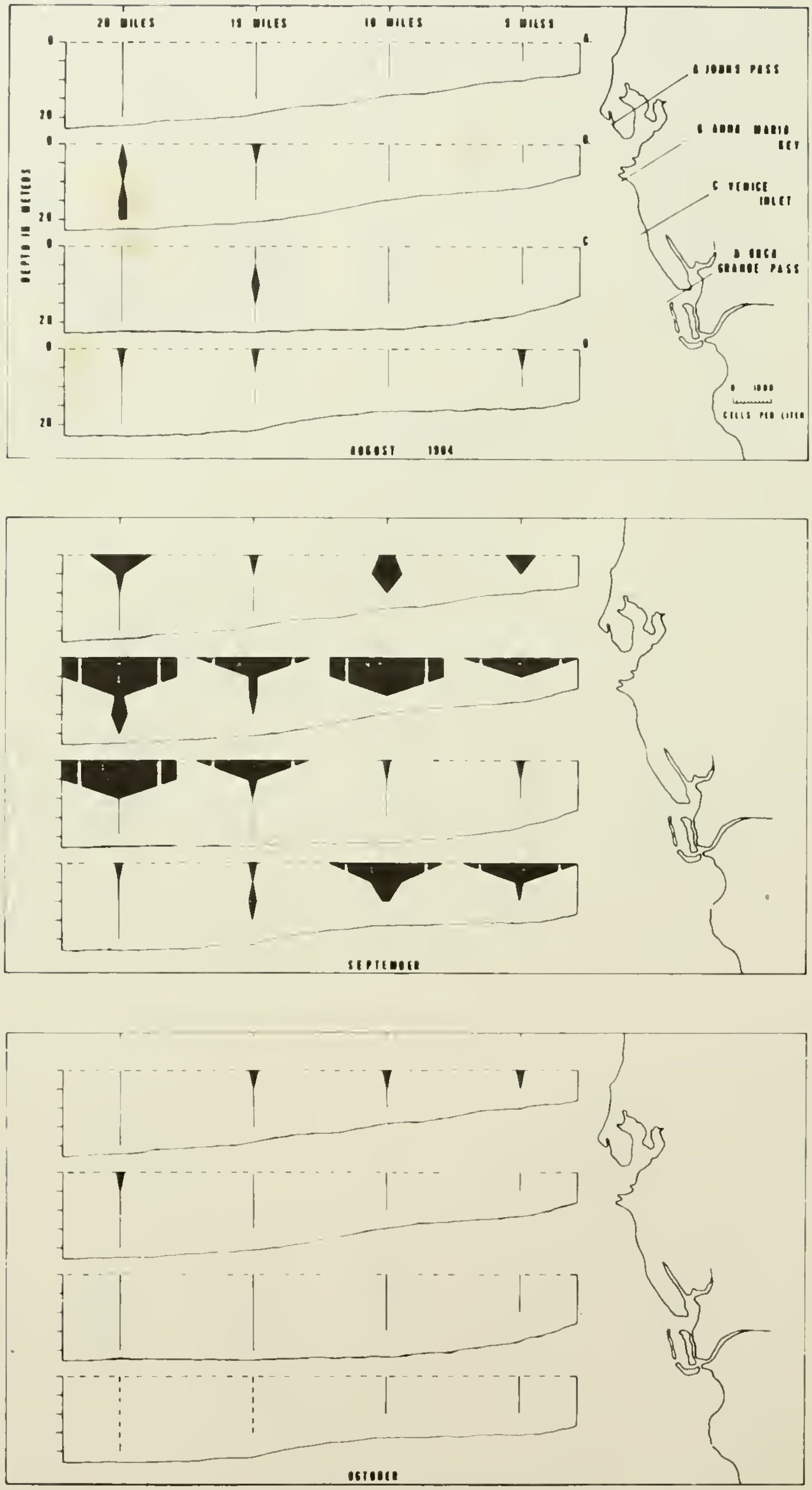

Figure 2(c).--Vertical and temporal distribution of G. breve at sampling areas along the west coast of Florida.

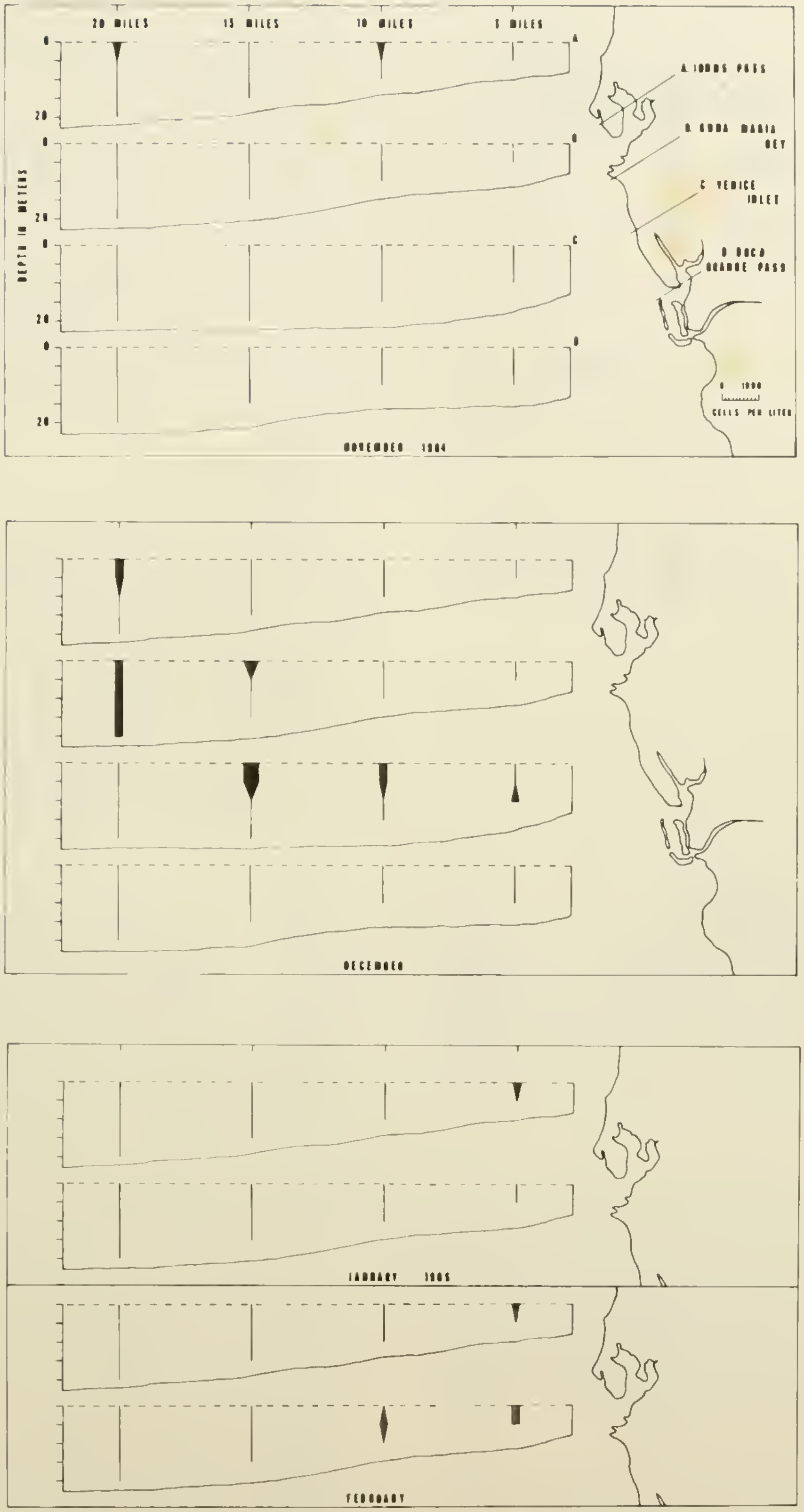

Figure 2(d).--Vertical and temporal distribution of G. breve at sampling areas along the west coast of Florida.

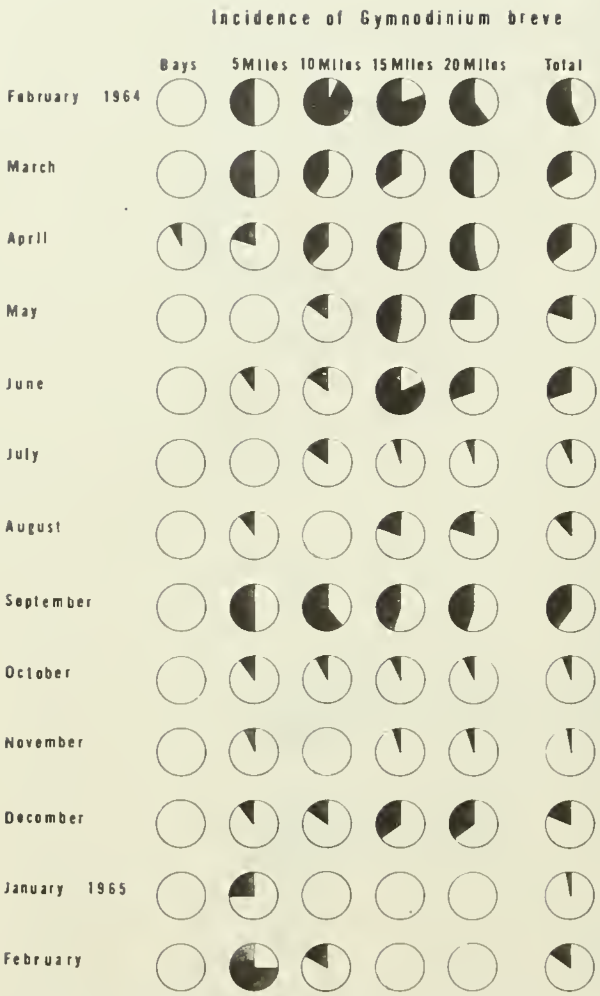

Figure 3.--Incidence of G. breve (percentage of total samples containing the organism) by month and distance from shore along the west coast of Florida, February 1964 to February 1965. Data are combined for Tampa Bay and Charlotte Harbor, and for the four series of stations shown in figure 1. Solid black circle is equal to 100 percent.

ENVIRONMENTAL FACTORS

The distribution and abundance of marine phytoplankton are influenced by temperature and salinity. The geographic distribution of phytoplankton is governed by temperature. The latitudinal occurrence of phytoplankton in neritic and estuarine areas is controlled primarily by salinity fluctuations which, in turn, are influenced by precipitation.

Temperature

Maximum water temperature (31.1° C.) was observed in August at Charlotte Harbor, and the minimum (13.8° C.) in February, 27.8 km. (15 miles) off Johns Pass, near the bottom. Low temperatures extended from December through March in most of the area (table 1). Warming began in March, and temperatures were highest in July and August. Temperature decreased in most areas from September through December. Off Johns Pass this decline continued through February 1965 and off Anna Maria through January.

Thermal gradients were negative in March and September, 27.8 km. (15 miles) and 37.1 km. (20 miles) offshore. The maximum gradient (3.7° C.) occurred in September, 37.1 km. (20 miles) offshore. For the remaining months, vertical variations of temperature never exceeded 1.6° C., but they were greater than 1° C. 15 times.

Precipitation

Heavy rainfall is often given as a likely factor in the production of red tide (Nümann, 1957). Although it has not always been associated with outbreaks of Florida red tide, it must be considered as one of the factors favoring red-tide outbreaks.

Precipitation during 1964 at St. Petersburg, Bradenton, Punta Gorda, and Fort Myers was well below the long-term means, although it was 16.15 cm. (6.36 inches) above the mean at Tampa (table 2). The lack of red-tide outbreaks during the present study was coincidental with the relatively low rainfall.

Salinity

The maximum salinity (37.10 p.p.t.) was 20 miles off Venice Inlet, near the bottom, in July; the minimum (17.83 p.p.t.) was in Hillsborough Bay, at the surface in April. Seasonal changes of salinity are similar at all offshore stations (fig. 4). Monthly changes in salinity were more pronounced at stations 5 and 10 miles offshore than at 15 and 20 miles. Salinity increased steadily at most stations from February through July and began to decline in August during the rainy season. It increased in November but remained below the maximum summer value from November through February.

In terms of distance from shore, salinity increased progressively from 5 to 20 miles offshore at all transects only in April and December (fig. 4). Existence of water masses with reduced salinity at stations 20 miles offshore was particularly obvious in September.

Salinity increased with increasing depth at offshore stations throughout most of the investigation. The gradient exceeded 1 p.p.t. during February, June, August, September, October, and November.

Table 1.--Mean monthly temperatures of water samples (all depths combined) at stations along the west coast of Florida, 1964-65

(Station locations are shown in figure 1)

Sampling area and month	Distance offshore			
	9.3 km. (5 miles)	18.5 km. (10 miles)	27.8 km. (15 miles)	37.1 km. (20 miles)
Johns Pass				
1964:	°C.	°C.	°C.	°C.
February	14.6	14.4	14.9	14.9
March	15.6	15.5	15.4	17.6
April	21.9	21.4	21.0	20.3
May	24.8	24.8	24.7	24.4
June	28.2	28.1	28.0	27.6
July	29.3	29.4	29.5	29.5
August	29.5	29.3	29.2	29.4
September	27.7	28.2	27.8	27.1
October	23.9	24.1	24.2	24.6
November	23.1	23.2	22.9	22.6
December	20.3	20.8	21.4	21.8
1965:				
January	19.2	19.2	19.2	19.4
February	18.5	18.3	18.3	18.3
Anna Maria Key				
1964:				
February	15.7	15.7	15.2	15.4
March	20.5	19.7	19.0	18.3
April	23.5	22.9	22.8	22.5
May	25.7	25.8	25.3	25.2
June	28.9	28.6	28.2	27.2
July	29.7	29.6	29.5	29.5
August	29.8	29.6	29.8	29.6
September	27.7	27.7	27.6	27.4
October	23.6	23.8	24.0	23.6
November	24.0	24.0	24.0	23.5
December	18.4	18.3	19.0	19.4
1965:				
January	16.2	17.2	17.6	17.9
February	19.1	18.9	18.8	18.7
Venice Inlet				
1964:				
February	15.2	15.4	15.3	16.4
March	20.4	19.6	18.9	19.2
April	23.3	23.0	22.6	22.3
May	26.0	25.9	25.6	25.3
June	28.3	28.3	28.1	27.8
July	29.7	29.7	29.7	29.8
August	29.8	29.8	29.8	29.8
September	27.0	26.8	26.6	26.4
October	22.1	22.4	22.7	23.0
November	23.2	22.9	22.8	22.6
December	21.0	21.0	21.1	21.8

Table 1.--Continued

Sampling area and month	Distance offshore			
	9.3 km. (5 miles)	18.5 km. (10 miles)	27.8 km. (15 miles)	37.1 km. (20 miles)
Boca Grande Pass				
1964:				
February	15.3	15.0	14.6	15.0
March	21.2	21.1	20.6	20.0
April	24.0	23.7	23.1	22.7
May	27.0	26.4	26.2	25.6
June	28.9	28.7	28.3	28.2
July	29.7	30.1	30.2	30.1
August	30.1	30.1	30.0	29.9
September	27.2	27.4	27.4	27.3
October	22.2	22.6	-	-
November	21.9	23.1	23.5	22.3
December	20.6	21.6	21.6	21.7

Sampling area and month	Locations	
	Upper 2 stations, (Old Tampa Bay and Hillsborough Bay)	Lower 2 stations (Tampa Bay)
Tampa Bay		
1964:	°C.	°C.
February	14.4	14.4
March	20.4	20.8
April	21.2	21.8
May	24.6	24.9
June	30.0	29.8
July	29.9	29.8
August	29.5	28.0
September	28.6	28.8
October	24.2	24.5
November	22.4	22.2
December	18.8	18.9
1965:		
January	18.8	19.0

	Locations	
	Upper station	Lower station
Charlotte Harbor		
1964:	°C.	°C.
February	15.4	15.4
March	21.3	21.5
April	24.8	25.1
May	27.4	27.4
June	29.1	29.7
July	30.3	30.5
August	30.8	30.9
September	29.2	28.0
October	21.9	21.9
November	23.4	22.4
December	21.9	22.0

Table 2.--Monthly and annual precipitation (inches) at selected locations along the west coast of Florida, 1964-65

(Compiled from data of the U.S. Enviromental Science Service Administration. Long-term means (where data are available) are shown by numbers in parentheses.)

Weather centers	1964													1965	
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Jan.	Feb.
Clearwater.................	5.87	7.22	5.21	1.42	2.54	2.31	9.38	9.29	8.02	2.68	0.91	5.02	59.87	1.13	3.91
St. Petersburg.............	3.30 (2.46)	5.97 (3.01)	4.00 (3.67)	0.80 (3.21)	2.30 (2.58)	3.86 (6.32)	7.86 (9.22)	5.61 (8.96)	2.52 (8.37)	1.45 (3.85)	.87 (1.66)	1.39 (2.10)	39.93 (55.27)	0.92 (2.46)	3.61 (3.01)
Tampa......................	5.08 (2.13)	5.37 (2.84)	3.92 (3.75)	.53 (2.84)	3.58 (2.85)	6.64 (7.28)	9.75 (8.62)	10.73 (8.24)	5.89 (6.89)	2.86 (2.78)	.38 (1.46)	3.19 (1.89)	57.92 (51.57)	1.56 (2.13)	2.57 (2.84)
Bradenton..................	3.74 (2.48)	5.25 (2.78)	3.73 (3.38)	.63 (2.80)	2.95 (2.61)	7.64 (6.76)	7.16 (9.03)	4.87 (9.77)	4.78 (8.24)	0.85 (3.52)	.67 (1.79)	2.03 (1.98	44.30 (55.14)	1.55 (2.48)	2.96 (2.78)
Sarasota...................	3.87	5.80	4.74	.88	1.69	6.76	5.27	4.60	7.13	.59	.28	1.38	42.99	2.73	3.05
Venice.....................	3.68	4.92	3.10	.62	1.49	2.00	8.78	4.71	4.78	.86	.54	2.05	37.53	1.06	3.60
Punta Gorda................	1.60 (1.76)	4.62 (2.43)	0.57 (2.84)	.28 (2.90)	1.31 (3.50)	3.37 (8.87)	7.39 (7.80)	3.88 (6.96)	5.57 (8.56)	1.07 (4.08)	.18 (1.27)	1.26 (1.58)	31.10 (52.55)	-- (1.76)	-- (2.43)
Ft. Myers..................	2.88 (1.52)	3.30 (2.21)	2.12 (2.62)	.80 (2.64)	0.50 (3.85)	4.58 (8.96)	2.28 (9.08)	4.26 (7.38)	9.45 (8.50)	1.38 (4.09)	.22 (1.20)	1.06 (1.29)	32.83 (53.34)	1.24 (1.52)	2.99 (2.21)
Captiva....................	2.64	2.83	2.63	1.33	1.51	5.35	5.00	2.31	6.24	2.98	.09	1.14	34.05	1.68	3.60

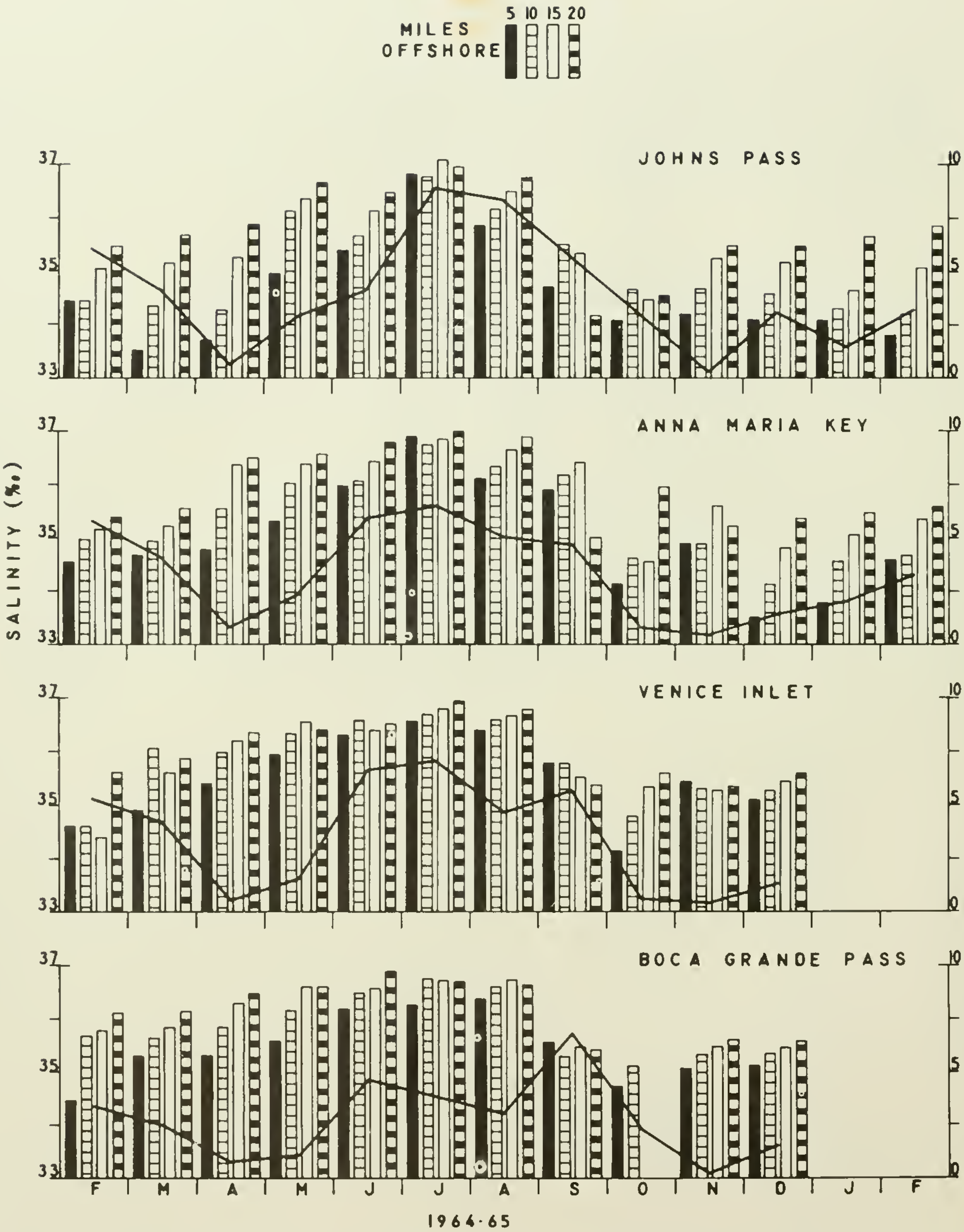

Figure 4.--Monthly mean salinity and precipitation at stations along the west coast of Florida, February 1964 to February 1965. Mean salinities (samples taken at 5-m. intervals in the water column) are shown by vertical bars; superimposed graphs denote precipitation.

Salinities were higher at stations in Charlotte Harbor (from 15.35 to 35.52 p.p.t.). Salinity in Tampa Bay may vary with the stage of the tide by as much as several parts per thousand during a 24-hour period (unpublished data, Bureau of Commercial Fisheries Biological Laboratory, St. Petersburg Beach, Fla.). Since the Bay stations were sampled without regard to tidal stage, the salinities determined may not represent temporal changes for the area.

RELATION OF TEMPERATURE TO OCCURRENCE OF GYMNODINIUM BREVE

Several studies have been made on the effect of temperatures on G. breve under field conditions and in the laboratory. Aldrich (1959), who studied the effect of temperature upon bacteria-free cultures of G. breve, reported some survival below 7° C. and a slowing down at 15° C. Seven years of field data analyzed by Rounsefell and Nelson (1964) indicated that G. breve thrives from 16° to 27° C., but that outside this range the organism occurs only in small numbers. The adverse effect of low temperature upon blooms of G. breve was observed in 1957 (Finucane, 1958). Concentrations were reduced to a few cells per liter after the water temperature dropped to 9.9° C.

In our study, G. breve was observed at temperatures from 13.8° to 30.6° C. The highest numbers of samples containing the organism were recorded within the ranges from 14.0° to 15.9° C. and from 26.0° to 27.9° C. (table 3). Incidence was low at the maximum and minimum temperatures. Cell densities greater than 1,000 per liter were recorded at 26.0° to 27.9° C.

The relation between the occurrence of G. breve and temperature is difficult to determine from our data because of the low incidence and concentrations encountered. On the basis of laboratory studies by Aldrich (1959) and field observations by Finucane (1964) and Rounsefell and Nelson (1964), the temperatures observed were generally favorable for the proliferation of G. breve. The

Table 3.--Temperature and salinity ranges within which G. breve occurred in the coastal waters of west Florida (February 1964 through February 1965)

Range (°C.)	Temperature			
	Samples	Positive samples	Percentage of positive samples	Percentage of positive samples within this range
	Number	Number	Percent	Percent
12.0-13.9.........	3	1	33.3	0.5
14.0-15.9.........	73	40	54.8	19.8
16.0-17.9.........	24	9	37.5	4.4
18.0-19.9.........	95	23	24.2	11.4
20.0-21.9.........	108	27	25.0	13.4
22.0-23.9.........	147	17	11.6	8.4
24.0-25.9.........	90	17	18.9	8.4
26.0-27.9.........	95	40	42.1	19.8
28.0-29.9.........	168	22	13.1	10.9
30.0-31.9.........	43	6	14.0	3.0
Total............	846	202	274.5	100.0

Range (p.p.t.)	Salinity			
	Samples	Positive samples	Percentage of positive samples	Percentage of positive samples within this range
	Number	Number	Percent	Percent
0.0-20.9.........	25	0	0	0
21.0-22.9.........	19	0	0	0
23.0-24.9.........	22	0	0	0
25.0-26.9.........	14	0	0	0
27.0-28.9.........	8	0	0	0
29.0-30.9.........	13	0	0	0
31.0-32.9.........	12	0	0	0
33.0-34.9.........	166	44	26.5	21.9
35.0-36.9.........	554	156	28.2	77.6
37.0-38.9.........	10	1	10.0	0.5
Total............	843	201	64.7	100.0

absence of extensive blooms of G. breve reported here is probably attributable to factors other than unfavorable temperature.

RELATION OF SALINITY TO OCCURRENCE OF GYMNODINIUM BREVE

Laboratory and field studies have been made also on the effect of salinity on G. breve. In bacteria-free cultures, Aldrich and Wilson (1960) observed good growth within the salinity range 27 p.p.t. through 37 p.p.t., and poor growth at values lower than 24 p.p.t. or higher than 44 p.p.t. In media with a salinity of 13.7 p.p.t. or less, no live cells of G. breve were detected 1 day after innoculation. Field data on occurrence of G. breve at various salinities vary (table 3), and agree only partially with the laboratory observations by Aldrich and Wilson (1960). The most favorable salinity range for growth of G. breve under natural conditions probably is between 21 and 37 p.p.t. (Finucane, 1964). According to Rounsefell and Nelson (1964), the upper salinity limit for good growth appears to vary with temperature, and salinity becomes limiting at 37 p.p.t. when temperature exceeds 23° C.

In our study G. breve occurred at salinities from 33.68 to 37.01 p.p.t. The majority of samples containing the organism were from water of salinity of 35.0 and 36.9 p.p.t. (table 3). Highest counts were during periods of reduced salinity (February and September--see figs. 2a and 2c). G. breve occurred only once in samples with salinity above 37.00 p.p.t., and in samples with salinity below 33.0 none were found.

The salinities at which G. breve occurred in our study fell within the range at which Aldrich and Wilson (1960) obtained good growth under laboratory conditions. Furthermore, on the basis of salinities observed by others (table 4), conditions in the area of investigation were favorable for blooms of G. breve even though no outbreak appeared. Thus our observations support the view that favorable salinity alone may not be the major factor in the proliferation of G. breve (Aldrich and Wilson, 1960; Dragovich, 1963; Finucane, 1964).

Table 4.--Salinity ranges within which Gymnodinium breve was reported under field conditions

Favorable range	Source
P.p.t.	
21.0-36.9.........	Finucane (1964)
31.0-34.00........	Hela (1956)
32.5-33.2.........	Ketchum and Keen (1948)
33.49-34.50.......	Chew (1953)
35.2-36.7.........	Dragovich (1961)
33.0-37.0.........	Odum, Lackey, Hynes, and Marshall (1955)
35.5-37.0.........	Gunter, Williams, Davis, and Smith (1948)
30.5-37.0.........	Rounsefell and Nelson (1964)

THE ROLE OF LAND NUTRIENTS AND PRECIPITATION IN THE DISTRIBUTION OF GYMNODINIUM BREVE

Nutrients from land drainage play an important role in outbursts of phytoplankton (Wilson and Collier, 1955; Lucas, 1955; Wilson, 1951; Nümann, 1957). A reduction in salinity in coastal waters is usually the first condition associated with periods of rainfall and increased land drainage. Offshore salinity was above 35.00 p.p.t. in 80.1 percent of the observations during the period of study; thus the offshore environment was essentially marine most of the time. Consequently, additions of nutrients via land drainage may have been insufficient to produce conditions required for lethal red-tide blooms.

On the basis of the incidence and counts of G. breve, the favorable conditions for its proliferation fell during February, March, and September 1964, the months of heavy rainfall and reduced salinity. Wilson in a simultaneous and independent investigation tested the suitability of waters from the study area for growth of G. breve in unialgal cultures (personal communication).[2] He found that the water was most suitable for growth of the organism in February, March, August, September, and October 1964.

COMPARISON OF DISTRIBUTION OF GYMNODINIUM BREVE IN 1964-65 WITH THAT PREVIOUSLY REPORTED

The seasonal, spatial, and vertical distribution of G. breve was essentially the same as observed during other non-red-tide years off the coast of west Florida (Finucane, 1964; Rounsefell and Nelson, 1964). Usually the organism was absent in bays but present in neritic areas. Our observation that G. breve is a relatively stenohaline organism which, during a non-red-tide year, occurs in low concentrations in the neritic waters of west Florida is in agreement with the findings of Finucane (1964), Aldrich and Wilson (1960), Dragovich (1963), and Rounsefell and Nelson (1964).

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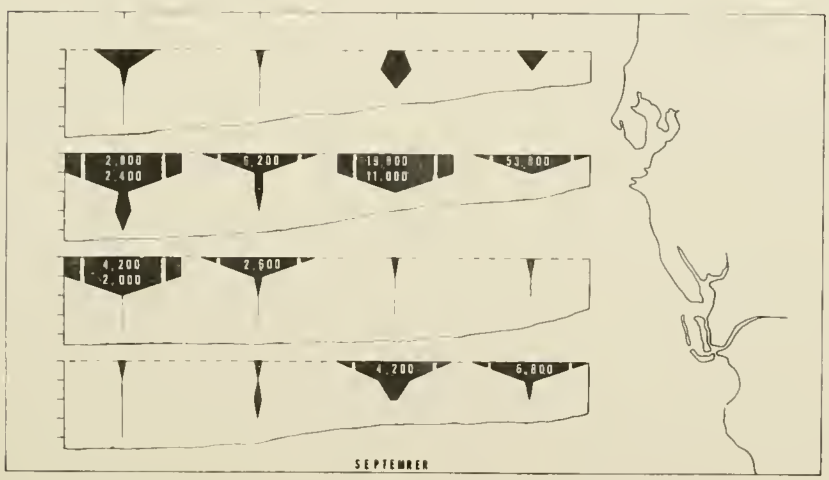
Distribution and occurrence of _Gymnodinium breve_ on the west coast of Florida, 1964-65, by Alexander Dragovich and John A. Kelly, Jr. U.S. Fish and Wildlife Service, Special Scientific Report-Fisheries No. 541, p. 6.



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